Nuclear Chemistry Notes

INTRODUCTION

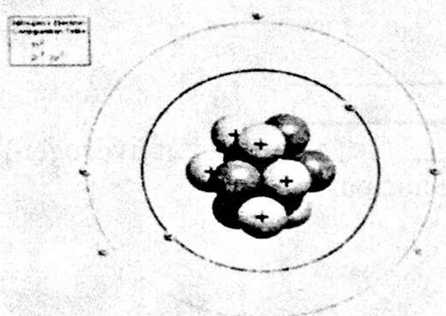
•**Nuclear chemistry** – subfield of chemistry dealing with ____________________ and nuclear processes, properties and reactions

•"Nuclear" = involving the ____________________

- Why do you care about nuclear chemistry? List at least 3 examples
  ____
  ____
  ____

REVIEW

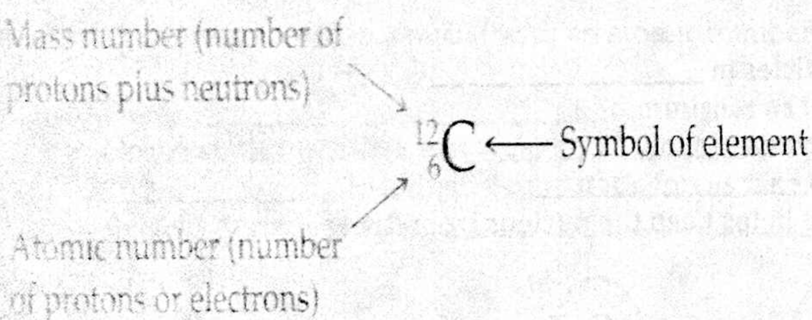
The ATOM



a. What element is presented?
____

b. How do you know? There are ______ protons and electrons

The NUCLEUS



•The nucleus is comprised of ____________and ______________ (called **<u>nucleons</u>**).

•The number of protons is the ____________________________.

•The number of protons and neutrons together is effectively the ______________ of the atom.

ISOTOPES

•Not all atoms of the same element have the same mass due to different numbers of neutrons in those atoms.

•For example, the following are three naturally occurring isotopes for uranium:

–Uranium-234	Atomic number = ______	Neutrons = ______
–Uranium-235	Atomic number = ______	Neutrons = ______
–Uranium-238	Atomic number = ______	Neutrons = ______

UCLEAR REACTIONS vs CHEMICAL REACTIONS/CHANGES

- Nuclear reactions involve the ________________ (protons and neutrons) while "normal" chemical reactions involve ________________
- No matter which type of reaction or change, atoms like to become __________.
- In a chemical reaction or in bonding, atoms achieve stability by filling their ____________ electron shells (donate, accept, or share electrons)
- In nuclear reactions, atoms achieve stability by changes to their ________________ (emitting radiation)

WHAT HOLDS AN ATOM TOGETHER?

Answer – 2 FORCES

1. Electrostatic forces

–________________ AND repulsion between charged (e^- and p^+) particles

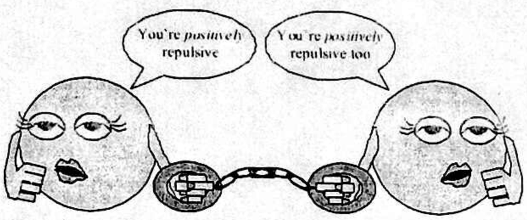
–Ex. e- and p^+ = ________________

p^+ and p^+ = ________________

–Strength of electrostatic forces: Short distances = ____________

Long distances = ____________

–Any element with more than one ____________ (i.e., anything but hydrogen) will have repulsions between the protons in the nucleus.



2. Strong Nuclear force-

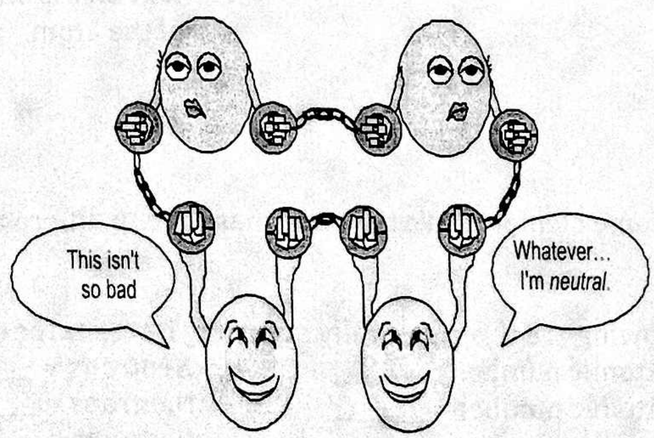
–Attraction between particles in ________________

–Strength:

Short distances = very ____________

Long distances = ________________

–The strong nuclear force helps keep the nucleus from flying apart.



-The strong force is a type of interaction that binds together protons and neutrons in a nucleus. Without it, the positively charged protons would repel each other and blow the nucleus apart

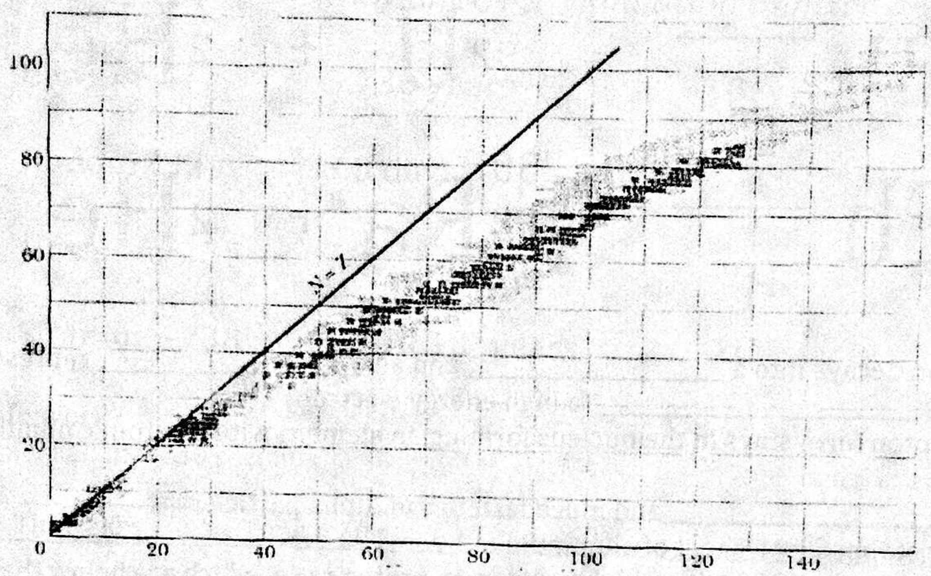
THE IMPORTANCE OF NEUTRONS

-Neutrons play a key role in ______________________ the nucleus.

-Therefore, the ratio of neutrons to protons is an important factor.

-For smaller atoms (*Atomic Number* ≤ 20), stable nuclei have a neutron-to-proton ratio close to 1:1. As nuclei get larger, it takes a greater number of ________________ to stabilize the nucleus.

-Anything lying below the "______________________" with too many neutrons will emit parts of the ______________ in order to become ________________.



*** There are no stable nuclei with an atomic number greater than ________

-The ______________________________diminishes as the nuclei become ________________, but the electrostatic forces are just weaker. Without the strong nuclear force holding the ______________ together, electrostatic forces take over, like charges ________________, and the nucleus decays, emitting ______________________.

RADIATION

- Unstable nuclei are "________________________," meaning they emit radiation
- **Radiation** – the particles that are released from the ______________ during radioactive decay
- **Radioactive decay** – ______________________ of an unstable atomic nucleus into one or more different ________________

TYPES OF RADIOACTIVE DECAY

During emission, the atom can change into a different ______________OR a different ________________.
There are several ways nuclei can decay. We will focus on:
1. ____________________________ 2. ______________________________ 3. ____________________

Alpha Decay

- Loss of an ____________________ (a helium nucleus, no electrons)
- Least penetrating
- ____________________and ________________ form of radiation
- Can be stopped by a piece of paper
- Deadly if released by atoms inside your body
- Common in elements with atomic numbers > ______

Alpha Particle:

$$^{238}_{92}U \longrightarrow {}^{234}_{90}Th + {}^{4}_{2}He$$

$$^{244}_{94}Pu \longrightarrow {}^{240}_{92}U + {}^{4}_{2}He$$

$$^{234}_{90}Th \longrightarrow {}^{230}_{88}Ra + {}^{4}_{2}He$$

Beta Decay

- Neutron decays into a ________________ and an ________________ representing the loss of a ________________________ (a high energy electron)
- The proton form stays in the nucleus forming an element with an atomic number 1 greater than the original
- More____________________and much faster than Alpha particles
- Can be stopped by a sheet of aluminum foil
- Common in elements with a high neutron-to-proton ratio, which are below the stable region

Beta Particle:

$$^{131}_{53}I \longrightarrow {}^{131}_{54}Xe + {}^{0}_{-1}e$$

$$^{84}_{35}Br \longrightarrow {}^{84}_{36}Kr + {}^{0}_{-1}e$$

$$\longrightarrow {}^{234}_{91}Pa + {}^{0}_{-1}e$$

Gamma Emission

- Loss of a ______________ (high energy radiation that almost always accompanies the loss of a nuclear particle
- No mass and no charge
- Travels at the speed of light
- Most penetrating
- Lead and concrete are used at barriers

Gamma Radiation

Measuring Radioactivity

One can use a device like a ____________________ counter to measure the amount of activity present in a radioactive sample.

Radioactive Decay Rates

Radioactive decay depends on the ______________ to ______________ ratio. An atom is generally stable if the ratio is about 1:1

Half-life: the __________ in which __________ of a radioactive substances decays

- Different isotopes have different half-lives; some are nanoseconds and others are billions of years

Common Radioactive Isotopes

Isotope	*Half-Life*	*Radiation Emitted*
Carbon-14	5,730 years	β, γ
Radon-222	3.8 days	α
Uranium-235	7.0×10^8 years	α, γ
Uranium-238	4.46×10^9 years	α

How does half-life work?

Classroom Example: half life = 30 seconds

	Time = 0 s	Time = 30 s	Time = 60 s	Time = 90 s	Time = 120 s
Number of students	400				

Radioactive Half-Life

- After one half life there is 1/2 of original sample left.
- After two half-lives, there will be 1/2 of the 1/2 = ______the original sample
- After three half-lives, there will be ½ of ½ of ½ = _______ of the original sample
- What fraction of the sample will be left after "n" half- lives? ______________
  - Example: What fraction of the original sample will be left after 4 half lives? __________

Radioactive Decay Rates

Use of isotopes with known half-lives:

1. Geologists calculate the age of rocks
2. Archaeologists determine the age of fossils and artifacts
3. Nuclear medicine

Half-Life Practice Problems

A sample of strontium-90 is found to have decayed to 1/8 of its original amount after 87.3 years. What is the half-life of strontium-90?

Transmutation

- Process of changing one __________ to another through __________ decay.
- Isotopes that give off __________ and __________ particles undergo transmutation.

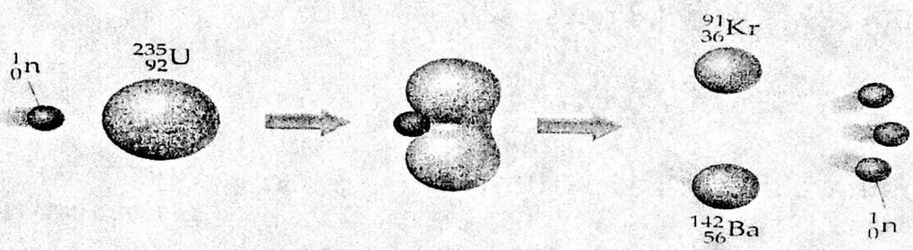
Energy in Nuclear Reactions

- There is a *tremendous* amount of ______________ stored in ______________.
- In ______________ reactions the amount of ________ converted to energy is minimal.
- However, these energies are many ________________ of times greater in nuclear reactions.
  - Example: 1 atom splitting is 6,700,000x's more energetic than ONE molecule of TNT exploding.

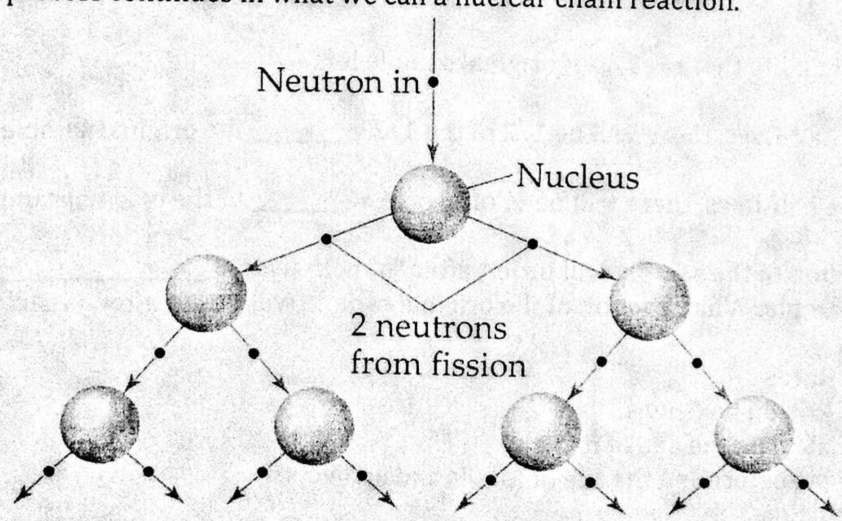
Nuclear Fission (splitting the nucleus of an atom)

- Nuclear fission is the type of reaction carried out in nuclear reactors to harness this energy.

$$^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{137}_{52}Te + {}^{97}_{40}Zr + 2\,{}^{1}_{0}n$$
$$^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{142}_{56}Ba + {}^{91}_{36}Kr + 3\,{}^{1}_{0}n$$



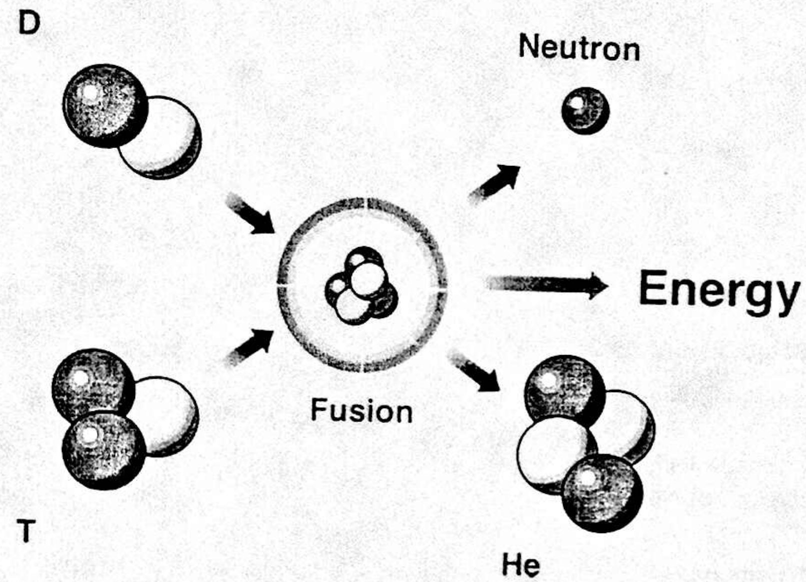
- A ______________ is used to bombard a heavy nucleus, which causes a __________ of that nucleus into 2 fragments, a release of ______________, and a release of ______________.
- Nuclear Fission can lead to a ______________.
  - The neutrons released in a fission reaction can start a chain reaction.
  - The neutrons released in the transmutation process can strike other __________, causing their decay and the production of more ______________.
  - This process continues in what we call a nuclear chain reaction.



- Chain reactions must be sustained with a ______________
  - If there are not enough ______________ nuclides in the path of the ejected neutrons, the chain reaction will die out.
  - Therefore, there must be a certain ______________ amount of ______________ material present for the chain reaction to be sustained: ______________.

uclear Fusion (combining nuclei)

- 2 light nuclei combine to form a ____________ nuclide releasing LOTS of ______________.
- Fusion powers the ______________(including the sun)
- Fusion would be a superior method of generating power.
  - The good news is that the products of the reaction are not radioactive.
  - The bad news is that in order to achieve fusion, the material must be in the plasma state at several million Kelvins. (Room temperature = about 23 Kelvins).



Nuclear Radiation Today

- You are exposed to nuclear radiation everyday. Some forms are harmful, others beneficial
- ______________________________________– the nuclear radiation that arises naturally from the sun, soil, rocks, and plants
- About __________ of our daily exposure comes from these sources...the other __________ comes from human-made sources (computers, smoke detectors, X-Rays)
- Levels of radiation absorbed by the human body are measured in _________ or millirems (1 rem = 1000 millirems)
- Safe limit = __________ millirems on top of background exposure
- Amount of exposure to natural radiation depends on location